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PATENT & TRADEMARK OFFICE

Air Force Invention No. AFB00500

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On 14 January 2005 .
DATE OF DEPOSIT

Thomas C. Stover 22,531
NAME OF APPLICANT, ASSIGNEE, OR REG. REP.

T C Stover 14 January 2005
SIGNATURE DATE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of
Mark Ahmadjian et al
Serial No. 09/862,788
Filed: 18 May 2001
For: **PLUME DETECTOR**

Group Art Unit: 2876
Examiner: A. Kim

Honorable Commissioner for Patents
Alexandria, VA 22313-1450

Sir:

Declaration under 37 CFR 1.131

I, Mark Ahmadjian of Cambridge MA, declare and say that:

1. I am one of the applicants in the above-identified application, filed as a Provisional Application, on 5-22-00.

2. USP 6,118,531 to Hertel et al, which issued 9-12-00, has been cited against claims 1-5, 7-9, 11, 13-16 in the above application. The Hertel patent lists an affective filing date in the UPSTO of 5-4-98.

3. Our invention, described in the above patent application, including the above claims, was completed in this Country, prior to the filing date of 5-4-98, as substantiated by our invention disclosure discussed below.
4. I further declare that this invention was diligently pursued by preparing and filing said disclosure with my employer, the USAF at Hanscom AF Base, MA, which, in turn, reported it to its Intellectual Property Office of ESC/JAZ, also at Hanscom AFB, which, in turn, searched the prior art re same and then, in consultation with me, prepared and filed the above Provisional application and within 12 months the above regular patent application in the USPTO.
5. As evidence of the above invention, I enclose as Exhibit A, a copy of excerpts of the invention disclosure, which include drawings of embodiments of the invention, similar to those shown in Figures 1 and 2 in the above application that was part of such invention disclosure. Again, I declare that such invention disclosure was prepared and dated well before 5-4-98, which invention disclosure was pursued with diligence, as stated above, to the filing date thereof in the USPTO.
6. I also declare that I do not know and do not believe that the invention has been in public use or on sale in the United States of America or any foreign country for more than one year prior to the filing date of my application and I have never abandoned my invention.
7. I further declare that statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and furthermore that these statements were made with the knowledge that willful false

statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

13 January 2005

Mark Ahmadjian., Declarant

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DISCLOSURE AND RECORD OF INVENTION

(This form is subject to the Privacy Act of 1974)

OMB No. 9000-0095
Expires July 31, 1995

PRIVACY ACT STATEMENT

AUTHORITY: 5 USC Chapters 45 and 54, 10 USC 1124; and EO 9397.
PURPOSE: To document inventions for consideration of patenting by the Air Force.
ROUTINE USES: In the event the invention is selected for further processing toward patenting the personal information provided by the inventor is used to process a cash award. SSN is used for positive identification.
DISCLOSURE IS VOLUNTARY: Failure to provide the requested information may delay patenting or prevent granting of a cash award.

INSTRUCTIONS

Fill in each blank with the requested information or enter "NONE" as appropriate. If additional space is needed for any items, continue on blank sheets, identify the item, and attach. This form must be signed and witnessed in the spaces provided on page 3. SUBMIT ONE ORIGINAL AND TWO COPIES OF THIS FORM.

1. DESCRIPTIVE TITLE OF THE INVENTION

Advanced Electro-Optical Missile Launch Warning Sensor

2. IDENTIFICATION OF INVENTOR(S)

NAME	AFSC OR OCCUPATIONAL SERIES	GRADE	DUTY SYMBOL	ADDRESS *(Street, City, State and Zip Code)*	DUTY ADDRESS	CITIZENSHIP	SSN	DUTY PHONE/FAX NO. *(DSN)*
Mark Ahmadjian	Chemist	GS-14	AFRL/VSO	32 Washburn Avenue Cambridge MA 02140	29 Randolph Rd., Hanscom AFB MA 01731-3010	US	035-32-2758	478-4799/5974
Ernest Ray Huppi	Engineer	GS-15	AFRL/VSB	30 Nancy Road Concord MA 01742	29 Randolph Rd., Hanscom AFB MA 01731-3010	US	529-48-3165	478-3715/5974
Donald R. Smith	Physicist	GS-15	AFRL/VSB	46 Exeter Street Newton MA 02465	29 Randolp Rd., Hanscom AFB MA 01731-3010	US	151-32-2376	478-3203/5974

3. SUMMARY OF THE INVENTION

We have developed an invention which detects missile launches from an overhead surveillance platform. This invention, Advanced Electro-Optical Missile Launch Warning Sensor, is a passive electro-optical sensor which detects the narrow electromagnetic spectral emissions created in a rocket engine plume when a missile is launched. The unique feature of this invention is that it is able to detect the missile's spectral emissions through clouds. Typical early missile launch warning systems using passive electro-optical sensors do not see through clouds and may not detect a missile launch at the instant of rocket engine ignition if the missile launch area is obscured by clouds. The time from rocket engine ignition to passing through a cloud layer may be up to thirty seconds. This invention, therefore, has the capability to provide thirty seconds of additional warning time of a launch than typical systems during cloudy weather conditions. To demonstrate the invention the atomic line emission of sodium (present in rocket engine plumes) at 589.6 nanometers (nm) was used. The invention is easily adaptable for other spectral emission lines which are scatted and transmitted through clouds.

The field demonstrations of this invention consisted of an aircraft mounted sensor and a sensor carried on-board an earth orbiting satellite. The aircraft system included a narrow-band filtered radiometer. The satellite system was a spectrographic imager. Both systems spectrally isolate the emission wavelength of interest and generate a radiometric measurement of the signal intensity. The aircraft and satellite sensors overflew a simulated rocket engine emission source at 589.6 nm and collected data. The collected data, data processing, and analysis show this invention is capable of detecting the narrow spectral emissions associated with a missile launch. The advantages of this invention over typical early warning sensors are it does not require cryogenic focal planes, does not require large optics, and can see a missile launch when the launch area is obscured by clouds.

Exhibit A

12. DESCRIPTION AND OPERATION

a. Purpose

The purpose of this invention is to detect the launch of a missile at the moment of rocket engine ignition and to do this when the missile launch area is obscured by clouds.

b. Background

Typical passive electro-optical early warning missile launch sensors use wide spectral band radiometers to detect the spectral emissions of a rocket engine plume. Spectral emission features may be associated with water, carbon dioxide and numerous other combustion and atmospheric chemical species produced in the burning of missile fuels. Because water in the earth's atmosphere decreases the transmission of spectral emissions at certain wavelengths, clouds may decrease the operational range of sensor to target for a typical sensor operating within a wide spectral band. A sensor able to "see through water" would offer an advantage in detecting a missile launch from an area obscured by clouds. By selecting a very narrow spectral range and at a wavelength where the water in clouds does not absorb the missile plume emissions a sensor could detect a missile launch under cloud conditions. The technology to conduct this task is now available and has been used for the invention described in this patent application.

c. Description, manner and process of making and using invention.

Introduction.

Spectral measurements of various solid- and liquid-propellant rocket plumes have shown the presence of strong narrow spectral line emissions from the alkali metals sodium (589.6 nm) and potassium (766.5 nm) in addition to those spectral emissions used by a typical missile warning system. Theoretical calculations indicate that emissions near the 589.6 nm wavelength should be efficiently transmitted through the atmosphere and clouds and thus should be detectable by a downward-looking sensor positioned above the clouds. The concept is applicable to any spectral emission for which water has transparency. To test this concept, a visible radiometric sensor with an interference filter (and later with an atomic line resonance filter) was developed and flown on an aircraft platform. In addition, high resolution spectral measurements from the earth orbiting Mid-Course Experiment (MSX) were successfully conducted. A ground-based sodium emission source to simulate a rocket engine plume was fabricated using sodium discharge lamps. Aircraft and satellite flight tests were conducted for different cloud types and conditions. These tests demonstrated the feasibility of detecting a missile launch with a narrow spectral sensor over an area obscured by clouds.

Description of concept and invention.

Prominent atomic emission features from the alkali metals sodium (Na) and potassium (K) have been observed with ground-based optical sensors in the first-stage plumes of both solid - and liquid-fuel rockets.[1,2] Strong Na and K features have also been seen in the second-stage plume as well as during the period following first-stage burn-out and before second-stage ignition. A prominent Na feature was also observed through heavy rain from a first-stage plume by a sensor at a range of 1.6 km.[3] As a result of these observations and theoretical calculations of multiple scattering through clouds, we designed, fabricated, and flew an invention which demonstrated the feasibility of detecting a missile launch through clouds with a narrow spectral band filtered sensor.

2.0 A narrow spectral band filtered sensor for airborne operation was designed, fabricated, and tested. This sensor shown schematically in Figure 1 consisted basically of a narrow-band filtered photometer (3), data acquisition electronics (4), and a notebook computer (5) to monitor and record the data.

The photometer had a 50 mm-diameter collecting aperture (2) and a full-angle field of view of 2.0 degrees. A Hamamatsu photomultiplier (model H6180-01) was used as the detector. A 10-nm-wide interference filter centered at 590 nm was used to pass sodium emissions and to reject the background. Typically, the sensor was flown at an altitude that was 2000 feet above the cloud tops. At this range the photometer footprint at the cloud tops was about 21 meters.

A lock-in amplifier manufactured by Stanford Laboratories (model SR510) was configured to synchronously rectify the signal from the photometer at twice the 50 Hz reference signal frequency. The analog output of the amplifier was fed to data acquisition electronics where digital samples were taken at a rate of 10 times per second. The sampled digital data was recorded on the hard drive of a Toshiba notebook computer. The notebook computer also provided a real-time display of the photometer output. A GPS receiver (6) recorded the flight path of the aircraft platform for post-flight data analysis.

A ground source (1) to simulate a rocket engine launch was fabricated using 180 Watt low-pressure sodium discharge lamps. Each bulb was approximately 1 meter long and rated at 33,000 lumens. The bulbs were assembled in pairs with a common reflector element to create 360 W lamps. These lamps were then arranged on the ground at Hanscom AFB in a pattern resembling the spokes of a wheel to create a source with an effective circular diameter of approximately 2 meters. Powered by a 50 Hz generator they produced a modulated output of approximately 26 W/sr.

3.0 The aircraft flight test program was conducted by the Air Force Research Laboratory (AFRL) and measured the diffuse transmission of the sodium ground emission source through clouds and determined the spatial distribution of the scattered radiation at the top of the clouds. The experiment consisted of viewing the cloud tops with an

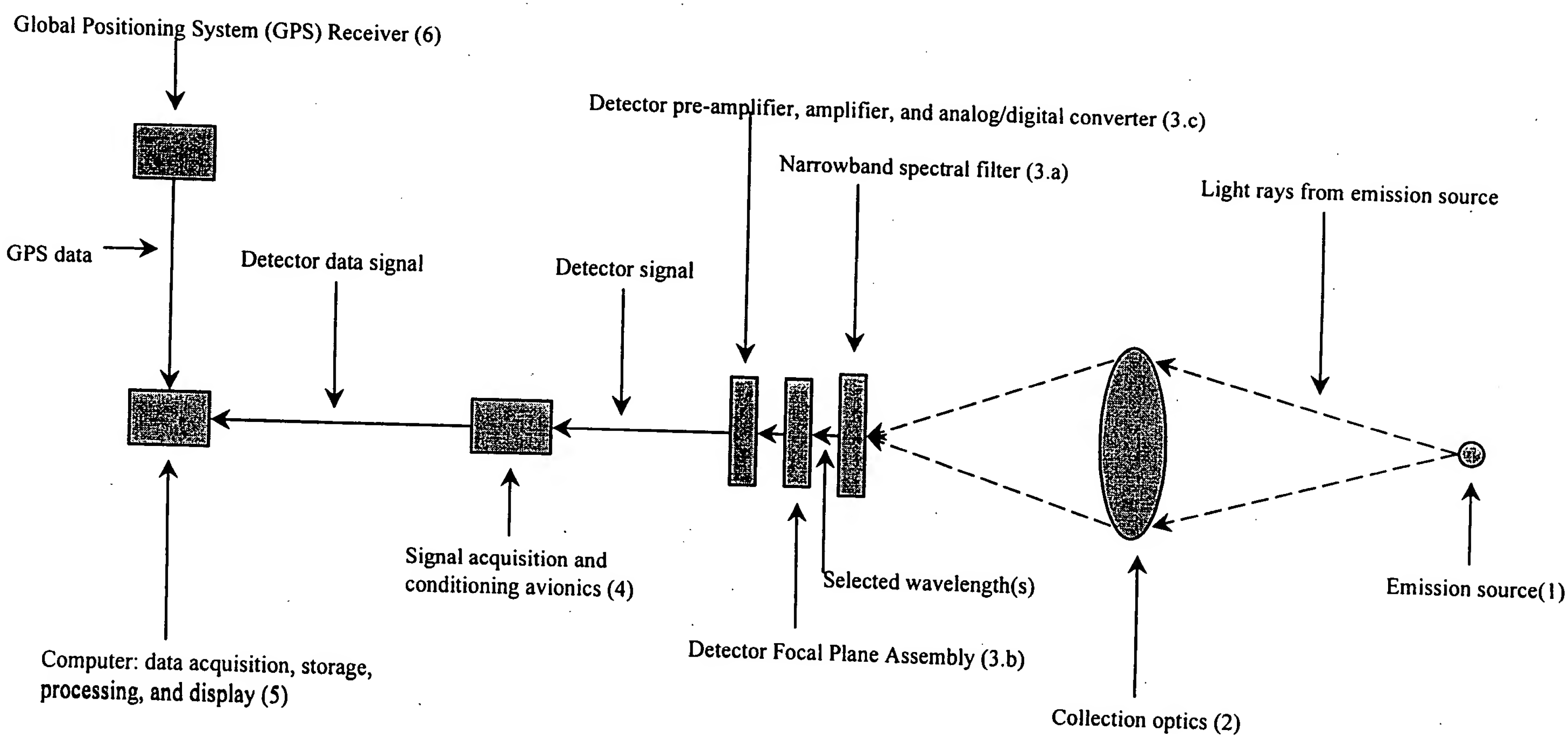
airborne sensor while the clouds were being illuminated from below by the ground-based sodium emission source. The basic experimental concept is illustrated in Figure 2. A vertical pointing TPQ 11 35 GHz (0.86 cm) radar, located adjacent to the sodium emission source was used to measure cloud top and bottom altitudes.

The sensor system was mounted in the aft compartment of a twin-engine Beechcraft Duchess aircraft. The sensor looked out through a window and periscope which were mounted in a compartment door. The periscope contained a mirror at 45 degrees and could be rotated to allow the photometer to view the cloud tops at any desired nadir angle. Most of the data was taken at a nadir angle of zero degrees, but a few measurements were conducted with nadir angles up to 60¡degrees A GPS receiver onboard the aircraft recorded the position of the aircraft as a function of time.

In order to minimize the photon background level, measurements were conducted at night. After the nighttime measurements had been successfully completed, the sensor was modified for daytime operation by replacing the 10-nm-wide interference filter with a much narrower (~ 0.005 nm) atomic line filter (ALF). The atomic line filter (also called a "Faraday atomic line filter" or simply just a "Faraday filter") was obtained from AstroTerra Corp, San Diego, CA. The filter incorporates a heated sodium vapor cell with a magnetic field between two crossed polarizers. The crossed polarizers block the background radiation while the signal polarization is rotated by 90¡, thus allowing it to pass through the filter. Polarization rotation in the magnetic field is due to the Zeeman effect which causes a separation in the optical absorption frequencies for right- and left- circularly polarized light. The passband frequency and bandwidth are dependent on temperature and magnetic field and can be adjusted over a relatively wide range. This filter was used in conjunction with a narrow band (0.5 nm) interference filter to help reject background radiation in the far wings. Unfortunately, our particular ALF was plagued by vapor cell degradation due to sodium depletion and other effects in the cell windows that have combined to degrade the filter performance and the results will not be part of this patent application. Future measurements will be conducted with a high resolution spectrometer capable of fine tuning to a specific wavelength of interest.

Several aircraft data collection flights were conducted over Hanscom AFB in the fall of 199[redacted]. These data flights were flown for two distinctly different "cloud" conditions. The first of these flights was conducted on September 4, 199[redacted]. This flight measured the transmission of the sodium ground source through a 1000 foot-thick stratus cloud located between 6000 - 7000 ft in altitude. Figure 3 shows the signal intensity measured through this cloud as a function of horizontal distance. The measured peak radiance was 4.5×10^{-10} W/cm^{2}sr and the spatial extent was approximately 3.9 km. On October 10, 199[redacted], with the aircraft flying at 10,000 feet, the sensor observed the ground source through a much thicker but less dense fog "cloud". This fog layer extended from approximately 1000 to 8000 ft. in altitude and was of a type generally referred to as "radiation fog". This type of fog is characterized by relatively small-diameter droplets (< 2 mm). The measured intensity through this fog layer versus horizontal distance in kilometers is shown in Figure 4. The peak brightness was 2.3×10^{-9} W/cm^{2}sr and was measured directly over the

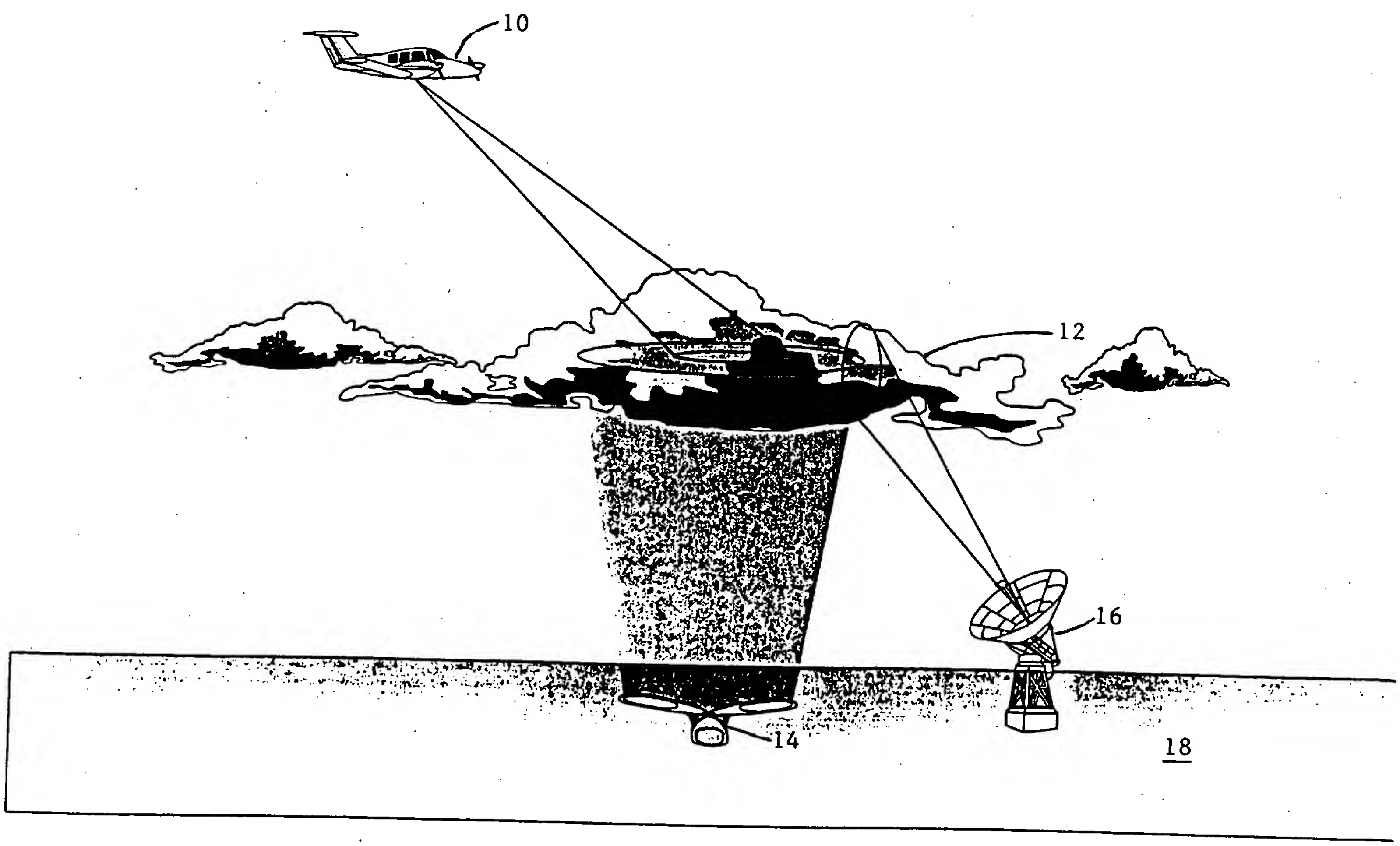
Advanced Electro-Optical Missile Launch Warning Schematic



(not to scale)

Figure 1

FIG 2



10 Sensor platform (aircraft or satellite)

12 Clouds in line of sight

14 Emission source - simulated rocket plume

16 Diagnostic radar - to measure cloud height & thickness

18 Earth's surface